Blue-Green Algae (Cyanobacteria) in Inland and Inshore Waters: Assessment and Minimisation of Risks to Public Health

Compiled by the Scottish Executive Health Department Blue-Green Algae Working Group

Scottish Executive Health Department 2007
Revised Guidance

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Foreword by Dr Harry Burns, Chief Medical Officer for Scotland

In the autumn of 1854, an outbreak of cholera claimed the lives of some 600 residents of the Soho area of London. In studying the distribution of these cases in the areas affected, a local doctor, Dr John Snow, developed a view that the source of the outbreak was the water pump in Broad Street. It is said that, at a subsequent meeting, Dr Snow managed to convince a sceptical board of guardians for the parish of St James, that there was sufficient evidence to warrant an appropriate intervention – the removal of the Broad Street pump handle. The handle was removed and the outbreak ended.

The story of Dr John Snow and the Broad Street pump handle holds a prominent place in the history of public health in the UK. Not only did it establish contaminated drinking water as the source of a major killer, it is also credited with marking the birth of modern epidemiology.

Now, some 150 years on, protection of the public health relies less on the inspired efforts of individuals but rather on what we often describe as "the organised efforts of society". However, ensuring the availablity of reliable sources of clean water remains a cornerstone of these efforts.

The original development of this document in 2002 and the subsequent implementation of its guidance have provided an excellent example of successful channelling of the organised efforts of the public health and the environmental agencies in Scotland. This joint working has continued in the development of this 2007 revision which now includes the provisions necessary to address the relevant responsibilities of the Scottish Executive under the European Council's revised Bathing Waters Directive of 2006.

I am grateful, therefore, to the members of the Blue Green Algae Working Group who have contributed to the revision of this document and I thank them for the opportunity to provide this introduction.

Dr Harry Burns
Chief Medical Officer for Scotland

Preface

This is the first revision of the guidance document under the same title that was published by the Scottish Executive Health Department in 2002.

The approach advocated for managing the risks to human and animal health of exposure to blue-green algal toxins continues to centre on production and implementation of “Local Action Plans”. These should be co-ordinated by the NHS Boards in Scotland and should be agreed by the various stakeholders identified herein.

This document includes guidance on the content and structure of these Local Action Plans and should be regarded as a resource to assist in their production, as well as fulfilling there requirements of Article8 (Cyanobacterial risks)of the Bathing Waters Directive(2006/7/EC).

The Scottish Executive Health Department (SEHD) proposes to review and, if necessary, re-issue this guidance document every five years. However, it is recognized that the value of this guidance lies in its practical implementation. The SEHD would therefore welcome feedback ,which should be addressed to the SEHD’s Scientific Adviser at St Andrew‘s House, Edinburgh EH13DG. Should this feedback indicate a specific need, then a further version of this guidance will be produced sooner.

Dr Colin Ramsay
Chairman of the Blue Green Algae Working Group

Glossary of abbreviations

COSHH	Control of Substances Hazardous to Health
EHO	Environmental Health Officers
FSA	Food Standards Agency
HSE	Health and Safety Executive
HPS	Health Protection Scotland
LPSs	Lipopolysaccharides
LAP	Local Action Plan
LAs	Local Authorities
LAEH	Local Authority Environmental Health
MHSWR	Management of Health and Safety at Work
NPIS	National Poisons Information Service
SAC	Scottish Agricultural College
SACVSD	Scottish Agricultural College Veterinary Science Division
SEPA	Scottish Environment Protection Agency
SEERAD	Scottish Executive Environment and Rural Affairs Department
SEHD	Scottish Executive Health Department
SEMD	Security and Emergency Measures Direction
SPIB	Scottish Poisons Information Bureau
WHO	World Health Organisation

1 Introduction

1.1 This report provides guidance to Directors of Public Health, to Heads of Environmental Health in local authorities and to others in Scotland on possible risks to public health of blue-green algae (cyanobacteria) in inland waters. The guidance, prepared by a Working Group established by the Scottish Executive Health Department, updates that given in the guidance document under the same title that was published by the Scottish Executive Health Department in 2002. It takes account of current World Health Organisation (WHO) guidance summarised in "Toxic cyanobacteria in water. A guide to their public health consequences, monitoring and management" (eds I Chorus and J Bartram) published in 1999 by E&FN Spon, London, on behalf of the WHO. The guidance given in this report also provides for Scottish compliance with the requirements of Article 8 of the revised Bathing Water Directive (2006/7/EC).

1.2 The remit of the Working Group was:

i. to review previous guidance in the context of advances in scientific knowledge and, in particular, to consider the implications for the public of exposure during recreation and work and of exposure from food and water;

ii. to review previous guidance on monitoring and risk assessment in the context of recent experience in Scotland and elsewhere; and

iii. to provide further guidance.

1.3 The membership of the Working Group is given in Annex A.

1.4 This document will continue to be updated every five years. It is accepted, therefore, that while certain details (such as contact details in Annex C) are correct at the time of issue, they are subject to obsolescence during this period.

2 Occurrence and appearance of blue-green algae

2.1 Blue-green algae occur in fresh-, brackish- and sea-waters throughout the world; in Scotland, they can occur in quantity in lochs, ponds, canals, reservoirs and coastal waters. While usually green, or blue-green in colour, they may be khaki, blue, black, dark brown or red.

2.2 When present in high concentrations, colonies of blue-green algae can often be seen with the naked eye: they may resemble fine grass cuttings or take the form of small irregular clumps or pinhead-sized spheres. Blue-green algae in high concentrations in the water column form 'blooms' and, when blown on to a downwind shore, form scums which may be centimetres thick. Scums may also be seen in slow-flowing rivers and streams downstream from lochs. Decaying scums, due to other naturally-occurring microbes or bright sunlight for example, can appear bleached as sky-blue, grey or white masses.

2.3 Blue-green algae may also grow on the bottom of shallow water bodies and on shoreline rocks. They occasionally form thick gelatinous mats, which may be exposed as the water level falls or may detach from the bottom and reach the shoreline. These mats are usually very dark in colour (black, dark brown or green) and cohesive and are sometimes mistaken for sewage.

2.4 Some types of algae especially blue-green algae form surface scums and growths of some water plants, particularly duckweed, might be mistaken for blue-green algae.

3 Public health concerns

3.1 Surveys in different parts of the world have found that between about 45% and 90% of blooms of blue-green algae produce toxins. These toxins are largely retained within the blue-green algal cells during their development and growth phases and are released, in the main, on cell death.

3.2 Blue-green algae of several genera can produce a range of toxins including neuro- and hepatotoxins and lipopolysaccharides. An algal bloom may contain more than one species, each producing the same or different toxins, either singly or in combination. In addition, the toxicity of one species might change over time to a pattern that might vary for different places on a particular water body. Further information on algal toxins is given in Annex B.

3.3 Evidence of toxicity comes from reports of the effects of exposure of people and of animals to algal blooms and from laboratory investigations of algal toxins.

3.4 In 1989, a group of soldiers took part in canoe training, including rolling and swimming exercises, at Rudyard Lake in Staffordshire. Two became severely ill with atypical pneumonia; others reported abdominal pains, vomiting, diarrhoea, blistering of the mouth and sore throats. Further incidents of effects on human health have occurred after recreational contact with blue-green algal scums and blooms in UK inland waters in recent years. The effects were probably associated with exposure to blue-green algae and ingestion of the toxin-containing blue-green algal scum.

3.5 Gastroenteritis, neurological effects and acute hepatocellular damage have been reported from other countries. Illnesses and deaths of haemodialysis patients, probably resulting from blue-green algal toxins in inadequately-treated water, occurred in Brazil in 1996. Further exposures of haemodialsis patients to blue-green algal toxins, followed by illness, occurred in Brazil in 2001.

3.6 Ingestion of hepatotoxic and neurotoxic scums of blue-green algae are reported to have caused the deaths of cattle, sheep, dogs and birds. There is also evidence that blue-green algal toxins have been major contributors to fish kills and deaths of other aquatic animals.

3.7 Another potential source of intoxication for both animals and humans is bioaccumulation of algal toxins in the food chain. The principal concern here would be accumulation of algal toxins in shellfish including freshwater and brackish-water mussels and in fish. However, no cases of intoxication from this source have been reported to date in Scotland.

3.8 Episodes of blue-green algal contamination of drinking water supplies occur periodically. In September 1997, a massive blue-green algal bloom affected the main water supply loch on Westray, Orkney Isles, and resulted in a ban on the use of water for drinking, cooking and washing. Large quantities of water treatment chemicals were needed to reduce blue-green algal concentrations to a level where even a reduced throughput could be maintained and aluminium levels in the final water eventually rose to a level considered unfit for consumption. The water had also become unacceptable due to taste and odour. No blue-green algal toxins were detected. The water authority arranged for potable water to be transported as bottled water and in tankers to serve the human population. Fortunately, the very large

cattle herd on the island at the time was able to continue to drink the loch water without ill effect. In July 2005, consumers of water from the Loch of Boardhouse supply in Orkney complained of an earthy taste and musty odour. A visual check of the loch identified green growth around the loch consistent with an algal or cyanobacterial bloom. Analysis confirmed mixed blue-green algal species, predominantly *Anabaena*, resulting in high levels of 2-methylisobornereol and geosmin. Blue-green algal toxin (microcystin) concentrations were below 1 microgram per litre. A temporary powdered activated carbon dosing plant was installed which improved the taste and odour of the final treated water. The blue-green algae had virtually disappeared by mid-August. Approximately 4,000 consumers were inconvenienced by disruption to their water supply and were supplied with bottled water. A similar problem with blue-green algae and geosmin tainting affected the taste and odour of water from the Glenfarg reservoir in 2006, also resulting in the use of carbon dosing.

3.9 There are occasional reports of animal deaths attributed by their owners to contact with blue-green algal scums. However, objective evidence is not always available to confirm an association with toxin exposure. In summer of 2003 there was good evidence to suggest that the deaths of two dogs in Fife were associated with ingestion of blue-green algal sludge at Town Loch in Dunfermline. Restrictions were imposed and were supported by ongoing monitoring and shoreline deposits were safely removed and disposed of. Another dog death on Shetland reported to SEPA in 2006 was investigated and cyanotoxin analysis suggested that toxin exposure was a strong candidate cause of death. Further incidents have been reported involving dogs and calves where the associations were circumstantial. As often occurs with such incidents, there were gaps in the recognition of a possible link and in the investigation, such that it was difficult to establish a definitive cause.

3.10 Surveillance by HPS using the Scottish Environmental Incident Surveillance System (SEISS), from 2002 onwards, identifies between 30 to 40 incidents being reported, by SEPA, Local Authorities and NHS Boards annually. Algal blooms are inherently complex (Paragraph 3.2) and assessment of the associated risks to public health is not straightforward. Such assessments should therefore take account of specialist advice (Annex C). Where advice is not immediately available, action of the kind described below may still be appropriate.

4 Local action plans

4.1 Arrangements for management of algal blooms should be documented in a "local blue-green algae monitoring and action plan" that includes provision for (i) assessing the nature and intensity of algal blooms, (ii) assessments of the risks to human and animal health, (iii) remedial and preventative actions that might arise from these assessments and (iv) providing information to the public.

4.2 Provisions in each of these areas ((i) to (iv) of paragraph 4.1) should be broadly in line with the respective guidance in Sections 5 to 8 of this document.

4.3 A "local action plan" (LAP) should be drawn up for each NHS Board area or, by arrangement, to cover more than one NHS Board area. NHS Boards should therefore take the lead in co-ordinating the provision of such a plan. LAPs should take account of existing multi-agency plans for managing waterborne hazards associated with the public water supply.

4.4 The LAP should be compiled and agreed by the principal stakeholders. These will normally include the Local Authority Environmental Health, Scottish Water, the local NHS Board and SEPA.

4.5 Particular consideration should be given to provisions for susceptible groups such as patients undergoing haemodialysis (Paragraph 7.3).

4.6 The LAP should state clearly the period of time for which it applies and should include provision for updating and re-issue.

4.7 The format and content for a sample LAP is provided here as Annex D.

4.8 Since the first version of this guidance document was published in 2002, the revised Bathing Waters Directive (2006/7/EC) has come into force. Article 8(2) of the Directive requires management measures to prevent exposure and inform the public in the event of a bloom or suspected bloom at identified bathing waters. It is intended that LAPs will be used as the management measures to fulfil that requirement.

5 Assessing the nature and intensity of blue-green algal blooms

General provisions

5.1 Wherever possible, assessment of blue-green algal populations should be co-ordinated between those with relevant interests. The principal aim should be to identify any need for further action. Provisions for assessments should be defined in the LAP and should include, as appropriate, procedures for visual inspection of the site, monitoring (sampling and analysis) and reporting and assessment of results.

Defining an assessment programme

5.2 The factors, physical, chemical and climatic, that lead to the development of blue-green algal blooms in inland waters (or to the growth and detachment of algal mats) are complex. However, for each individual waterbody, the frequency, duration and magnitude of such blooms often (though by no means always) follow a predictable annual cycle.

5.3 In Scotland most blooms occur between April and October though in some waters, blooms can occur outwith this period. Therefore, where activities with a high risk of exposure take place throughout the year, the possibility of continuing inspection and/or monitoring for example from November to March should be considered. The Bathing Water Directive requires that a profile of each designated inland and coastal site bathing water shall be undertaken to include identification of those bathing waters deemed to be susceptible to cyanobacterial proliferation. This will be undertaken by SEPA. The Directive also includes a particular obligation to ensure that any risks identified are properly managed during the official bathing season, which in Scotland runs annually from 1 June to 15 September.

5.4 The frequency, duration and magnitude of such blooms will affect the needs for inspection and monitoring. For present purposes, therefore it is useful to categorise waters in accordance with these "occurrence" factors, as shown in Table 5.1.

5.5 Column 3 of Table 5.1 gives general indications for the likely efficacy of monitoring for waters in each of the four categories. As a general rule, planned regular monitoring of blue-green algal cell populations for waters in Categories 1 and 4 will add little to existing knowledge. Planned monitoring might be of use for waters in Categories 2 or 3 but in circumstances where monitoring at fixed intervals of time is likely to miss blooms, only frequent visual inspection and reactive monitoring is useful.

Table 5.1:
Categorisation of waters in terms of the frequency and intensity of algal blooms. Column 3 indicates the likely efficacy of monitoring and inspections.

Category	Description of algal blooms	Implications for planned regular monitoring
1	Waters that consistently contain large populations of blue-green algae for many months in every year.	Not indicated. Will add little to what is already known.
2	Waters that have algal blooms for short periods in most years.	Of value, depending upon use made of waterbody. However, the ability to detect short blooms will depend on frequency of monitoring and some might be missed.
3	Waters that have only intermittent algal blooms in occasional years.	Of value depending upon use made of waterbody. Frequent sampling will yield many negatives and less frequent sampling might fail to detect short blooms.
4	Waters that never have algal blooms Not indicated.	All samples likely to be negative.

5.6 Decisions on the frequency of inspections and/or monitoring will also depend on other factors relating to the nature and frequency of use for the water in question. Circumstances will vary widely but the following general indications might apply:

i. Where exposure at recreational waters (including designated bathing waters) might be predictably persistent or recurring (Categories 1 or 2) it may be appropriate to provide permanent or semi-permanent warning notices, and to carry out inspections or monitoring to determine the beginning and end of the period of the hazard.

ii. For Category 3 recreational waters and for designated bathing waters visual inspection at intervals determined by the use of the water, with or without sampling, should be carried out.

iii. For waters in Categories 3 or 4 where blooms have been transient and infrequent and where the scope for exposure of people or animals is limited, frequent visual inspection and sampling are unlikely to be cost-effective.

5.7 In general, therefore, monitoring and inspection requirements should be determined by local circumstances and should be defined in the LAP.

Visual inspections

5.8 Visual inspections for blue-green algae should record the appearance and apparent concentration of algae in water. This will normally involve collection of samples of water from the furthest extent of reach from the shore using a suitable container. The presence of algae in the samples should be assessed, as distinct from general turbidity, by their characteristic colour and possible particulate appearance. Where possible, samples from a number of points including the lee and windward shores should be assessed and recorded in this way. Annex E gives further guidance on recognition and identification of algal blooms.

5.9 Visual inspections should particularly note the presence and quantity of algal scums on the surface of the water and on the shorelines.

Sampling and analyses

5.10 Methods of sampling and analysis should, wherever possible, follow guidelines provided by SEPA (Annex E).

5.11 In some circumstances, depending on the uses made of the body of water, proactive or reactive monitoring for the toxins themselves should be considered. This is also considered in Annex E.

5.12 In cases where health incidents (human or animal) have occurred with the possibility of blue-green algal poisoning as proximal cause or contributing factor, sample collection and analysis for toxins should be carried out for purposes of identification or elimination.

5.13 SEPA can provide an analytical service to identify and quantify algal blooms in samples taken by others from recreational waters and have specific duties regarding sampling of bathing waters. Scottish Water can also provide a similar service, including for samples taken from potable supplies that are thought to be at risk.

5.14 The LAP should define procedures for local assessment, recording, reporting and storage of monitoring data. For public or private drinking water, Scottish Water or the water-provider should provide customers or users with appropriate information to minimise any health risk from exposure to blue-green algal toxins. For bathing waters, SEPA or the beach owner/operator should provide bathers with appropriate information to minimise the health risk from exposure to the algal toxins.

5.15 Results from investigations should also ideally be reported, along with details of the incident, to HPS via the electronic surveillance system, SEISS.

6 Assessments of the risks to human and animal health

Responsibilities for risk assessments

6.1 Assessments of the risks to human and animal health from blue-green algal blooms are likely to be made for different purposes – and with different degrees of formality – by different "stakeholders" including:

- owners and employers, including Scottish Water; for their duties in law to employees, customers and to other members of the public;
- regulatory bodies; local authorities, for the assessment of risk to public health, and SEPA, for determination of sources of pollutants, their impact and regulation and their duty under the Bathing Water Directive;
- individuals; for their interests as employees or parents or in connection with their recreational interests.

6.2 The roles and responsibilities of these and other stakeholders are outlined in Section 9.

6.3 The responsibility for risk assessments by the owners of waters and by employers relates to their responsibilities to protect employees and others and, for Scottish Water, their customers.

6.4 Risk assessments by local authorities and SEPA are likely to be directed in part to determining inspection and monitoring priorities and schedules (Section 5). The interest of local authorities is primarily in determining the existence, or otherwise, in their areas of nuisances or hazards to health. That of SEPA is primarily in determining the state of the environment and in the regulation and control of sources of pollutants or in its duty under the Bathing Water Directive. A shared approach should be possible on specific waters where these interests require similar information.

Types of risk assessment

6.5 Risk assessments in respect of blue-green algal hazards in inland Scottish waters can be considered under three general headings, (i) generic assessments of the risk for the whole of each of the areas covered by the LAPs, (ii) pro-active assessments for individual waters, similar to and including those required under the Bathing Water Directive and (iii) reactive assessments in response to identified occurrence or consequences of algal blooms.

6.6 Each LAP should include an overall assessment of blue-green algal problems for the whole of the NHS Board area. This should provide a general summary of blue-green algal problems for the area and identify the waters that represent the greatest risks because of their history of algal blooms and/or their use.

6.7 Proactive individual assessments for all inland and inshore waters would be neither practical nor cost effective. These should normally be confined to those waters identified in the LAP as presenting the greatest risks. However, the responsibilities identified in paragraph 6.1 and

Section 9 (for example, those for employers) are not affected by any classification of waters in the LAP.

6.8 Stakeholders receiving reports on occurrences or consequences of algal blooms for waters relating to their interests should consider the need for a reactive risk assessment. This should aim to identify the magnitude and nature of the risks and define any interventions that might be required to lessen these risks.

Content of risk assessments for individual waters

6.9 Proactive risk assessments should include consideration of inspection and monitoring programmes and the need for appropriate action (such as erection of signs). They should take account, in structured ways, of information relating to any previous algal blooms (Table 5.1) and to the nature and intensity of use for the water in question.

6.10 Subsequent interventions would normally depend on the results of inspections and/or monitoring or the outcomes of any reactive risk assessments.

6.11 Reactive risk assessments (made in reaction to reports from the public of the appearance or consequence of algal blooms, suspected health incidents, or to inspections or monitoring) should consider how the water in question is used and the resultant risk to human and animal health (not the probability of occurrence of a bloom).

6.12 For either proactive or reactive risk assessments, therefore, assignment of waters to high, medium and low risk categories according to their use can help to prioritise the needs for inspection and/or monitoring and action. Table 6.1 gives outline descriptions of the features of waters falling into each of these categories.

6.13 A reactive risk assessment should define clearly the need for and nature and comparative merits of any interventions to mitigate the risks identified and for further inspection and/or monitoring.

Table 6.1:
Categories of risk related to the use of waters (and hence the probability and extent of exposure).

Risk category	Nature and intensity of use
High	Waters that are either consumed by people or animals or used for activities involving immersion or appreciable skin contact.
Medium	Waters for which the risk of ingestion of blue-green algal material or of toxins is small and appreciable skin contact with blooms is unlikely. Standing Waters that are used for spray irrigation of crops.
Low	Waters that are inaccessible or not used or are used only for angling, or other non-contact activities.

Defining categories for frequency of occurrence or risks for algal blooms

6.14 It is essential that different views about criteria for assignment of waters to each of the categories defined in Tables 5.1 and 6.1 are discussed by bodies seeking co-operative action on monitoring.

Templates for risk assessments

6.15 Examples of templates for proactive and reactive risk assessments are provided in Annex F. Stakeholders might prefer to use their own formats but, if so, the information contained in the risk assessment should be at least that indicated in Annex F.

Specific considerations for public drinking water supplies

6.16 There are a number of Scottish public water supply reservoirs where problems associated with algal growth recur. At these, the water treatment systems in place have been designed to cope or the water authority is able to use an alternative water source. Should circumstances arise where neither of these provisions applies, appropriate alternative measures would be put in place to ensure the safety of the water supply.

6.17 Scottish Water is required to comply with the Security and Emergency Measures Direction (SEMD). This requires it, amongst other things, to have emergency plans in place to cover such eventualities as loss of water supply (Paragraph 3.8) and to have routine liaison meetings about emergency issues with Local Authorities and Health Boards. These emergency plans are subject to an annual audit and certification by an independent consultant approved by the Scottish Executive. An audit report is submitted to the Scottish Executive by 31st March each year.

6.18 Consultation with Scottish Water in the production of LAPs for management of blue-green algae should ensure that these are compatible with any emergency plans drawn up under the SEMD.

7 Action

General requirements

7.1 Actions intended to reduce the probability of acute or delayed effects of algal toxins on people or animals are directed to reducing the probability of:

i. skin contact with or ingestion of algae in, or on the shore of, inland waters;

ii. ingestion of drinking water containing algae or algal toxins, and exposure to such water during bathing and showering;

iii. exposure to toxins by eating fish or shellfish from algae-rich waters; and

iv. delivery of contaminated water to patients undergoing haemodialysis.

7.2 Of these, 7.1(i) is the most likely. Acute effects from ingestion of publicly supplied drinking water containing algal toxins are considered unlikely in Scotland due to the effects of volume dilution and also the removal and degradation of toxins during normal water treatment processes. Scottish Water will take appropriate action to ensure the safety of supplies where algal blooms are identified. The risk of longer-term exposure to toxins from contaminated private supplies can be reduced by practical measures discussed later in this section or, if necessary, by substitution of an alternative supply or bottled water.

7.3 Particular attention should also be paid to the health risks for patients undergoing haemodialysis. In normal circumstances, algal toxins are effectively excluded by the reverse osmosis units that are used to treat the water supply to dialysis units in Scotland. However, the possible consequences of exposure to algal toxins (and indeed to other pollutants) due to system failure should be addressed. Local NHS Boards should ensure appropriate resilience for this threat.

7.4 It is prudent to consider possible health concerns about ingestion of blue-green algal toxins in affected foods. This includes consideration of (i) whether muscle tissue of fish from heavily affected waters should be eaten, (ii) the possibility of accumulation of microcystins on or in plants irrigated with water from sources containing cyanobacterial blooms and toxins, and (iii) the potential for accumulation of toxins on the external surfaces of edible plant material, for example, on salad plants.

7.5 Any proposed restrictions on the use of water because of the presence of an algal bloom should be based on a careful assessment of the resulting benefits and detriments. This assessment should, among other matters, take account of the circumstances of use and of the relevant World Health Organisation (WHO) guidance documents for drinking water and for recreational waters referred to in Paragraphs 7.6 and 7.7, as well as the requirements of Bathing Waters Directive 2006/7/EC.

Triggers for action

7.6 *The WHO (2004) Guidelines for Drinking Water Quality*. Third Edition. Volume 1. Recommendations. http://www.who.int/water_sanitation_health/dwq/gdwq3/en/, WHO,

Geneva, Switzerland, ISBN 92 4 154638 7) define a provisional value of 1µg/l of microcystin-LR (one of the commonly found hepatotoxins, in drinking water) for drinking water that is intended for lifelong consumption.

7.7 The equivalent WHO guidance document for recreational water is the 2003 Guidelines for safe recreational-water environments. Volume 1: Coastal and fresh-waters. http://www.who.int/water_sanitation_health/bathing/srwe1/en/, WHO Geneva, Switzerland. ISBN 92 4 154580 1.

7.8 The 2003 WHO guidelines for recreational-waters state that "Health impairments from cyanobacteria in recreational waters must be differentiated between chiefly irritative symptoms caused by unknown cyanobacterial substances and the potentially more serious hazard of exposure to high concentrations of known cyanotoxins, particularly microcystins. A single guideline value therefore is not appropriate." For recreational waters, therefore, the document recommends "a series of guideline values associated with incremental severity and probability of health effects" and these values are then defined for low, moderate or high probabilities of adverse health effects.

7.9 A copy of the relevant section from this WHO document [Section 8.7 Guideline Values] is appended here as Annex G. The guidance levels recommended by the WHO are summarised in Column 1 of Table 7.1. However, the advice given in Column 2 of Table 7.1 differs from that in the WHO Guidance document (Annex G) by recommending that, as an additional precaution, all four of the "typical actions" defined by the WHO for 100,000 cells cyanobacteria/ml be adopted at the lower level of 20,000 cells cyanobacteria/ml. (It should be noted here that the general equivalence implied in the final row of Table 7.1 between cell numbers and chlorophyll-a concentration (1µg chlorophyll-a per 2,000 algal cells) actually depends on cell type. Also, for some types, such as filamentous algae, individual cells are not easily identified or counted. These issues are considered in more detail in Annex E.)

Table 7.1
Guidance levels and related "typical actions" derived from current WHO guidance

Guidance level or situation	Typical Actions
Cyanobacterial scum formation in bathing areas	• Immediate action to control contact with scums; possible prohibition of swimming and other water-contact activities • Public health follow-up investigation • Inform public and relevant authorities
20,000 cells cyanobacteria/ml *or* 10 µg chlorophyll-a/l with dominance of cyanobacteria	• Watch for scums or conditions conducive to scums • Discourage bathing and further investigate hazard • Post on-site risk advisory signs • Inform relevant authorities

Actions in response to an algal bloom

7.10 Column 2 of Table 7.1 summarises the "typical actions" that should be taken to protect people who might come into contact with recreational waters affected at the extent indicated in Column 1. The WHO guidance also notes that "actual action taken should be determined in light of extent of use and public health assessment of hazard". Section 4 of this document refers to the need for LAPs to make provisions for such public health (risk) assessments and Section 6 gives general requirements.

7.11 Actions defined in Table 7.1 relate mainly to provision of information and advice and discouraging or prohibiting water-contact activities. Responsibility for these actions will vary according to ownership and use of the waters in question and these responsibilities should be defined in LAPs and in pro-active risk assessments (Annex F).

7.12 Information and advice might be provided by leaflets, warning notices, letters to stakeholders or public announcements (for example on local radio and by local press notices). Leaflets can provide more information to water-users than is possible in a warning notice and might be particularly appropriate in circumstances where there is extensive recreational use of a waterbody. More detailed consideration of public information provisions is given in Section 8.

7.13 In addition to advice aimed at minimising public health risks, advice should also be given to dog owners to protect dogs from ingestion of blue-green algal material in the water or on the shoreline. Parallel advice should be given to farmers to protect stock.

7.14 A suggested text for a warning notice is given in Annex H.

7.15 LAPs and proactive risk assessments should also consider the need for advice to avoid eating freshwater shellfish.

7.16 Fish should not be consumed if fish mortalities, or behavioral abnormalities, are observed at waterbodies containing mass populations of blue-green algae. In the event of blue-green algal scum being present, or blue-green algal cell numbers exceeding 20,000 per ml (Annex G), toxin analysis of fish intended for consumption should be carried out. Should toxins be detected by analysis, expert advice will be necessary on whether concentrations are sufficient to justify restrictions on the consumption of fish. The absence of taint does not indicate the absence of toxins since there is no correlation between the production of compounds affecting taste and odour and the production of toxins by blue-green algae. The liver and gut from fish caught in waters affected by blue-green algae should not be fed to pets.

7.17 LAPs and proactive risk assessments should consider the use of standing waters for irrigation of crops. While there is evidence of the possibility of internal accumulation of microcystins by certain plants, there is no convincing evidence of related health effects from human consumption. A more significant source of concern is where sprayed irrigation water becomes trapped in the centres of, for example, salad plants or where toxins are deposited on plant surfaces when sprayed water dries. Spray irrigation using water from sources containing cyanobacterial blooms and toxins also presents potential health hazards for

workers or bystanders who might be exposed to algal toxins by skin contact or by inhalation of spray drift. Occupational exposure is subject to the provisions for risk assessment arising from the Management of Health and Safety at Work Regulation 1999 (http://www.opsi.gov.uk/si/si1999/19993242.htm) but general advice from the WHO is that exposure of workers, bystanders and animals to spray irrigation water containing cyanobacterial toxins should be avoided. Advice should be given on precautions that are appropriate to local circumstances.

7.18 Table 7.1 also raises the possibility of "Public health follow-up investigation". This would be a matter for the local Director of Public Health but Paragraph 7.19 gives some general indications. Where any follow-up investigations are conducted it would be helpful to have the findings reported to HPS via the SEISS surveillance system to which NHS Boards have electronic access.

7.19 The long-term adverse effects of blue-green algal toxins are not fully understood. In cases of exposure to skin, a need for long-term follow-up is not indicated. If toxic bloom or scum have been ingested, medical or veterinary monitoring might be needed for adverse health effects and further advice should be sought (Annex C).

7.20 Where water is used for potable supply, toxin analysis should be planned and carried out as appropriate as an aid to hazard management.

7.21 Guidance levels for recreational waters are defined in terms of concentrations of the algae themselves rather than algal toxins. However, toxin analysis for recreational waters should be considered, depending on individual circumstances, in conjunction with advice from relevant sources (Annex C). Where a bloom is highly localised or confined to one area, the risks of exposure to significant quantities of toxin are likely to be low except where there is immersion in or ingestion of water in close proximity to the bloom itself.

7.22 Pre-emptive action should also be considered if, from knowledge of the water and recent weather, the probability of bloom formation is judged to be high.

Action to prevent blue-green algal blooms

7.23 In water bodies where persistently high algal concentrations occur or regular blooms take place (Categories 1 and 2 in Table 5.1), and where the attendant risk is categorised as "High" (Table 6.1) the source(s) of the problem should be established, and where possible, appropriate action taken. These measures should be enacted in consultation with SEPA and Scottish Water.

7.24 Algal blooms can result from a combination of natural factors, including availability of nutrients and light, water temperature and wind conditions and can be increased due to human impacts, e.g. excessive nutrient discharges. Availability of nutrients is a principal concern, as they are essential for plant and algal growth and blue-green algal blooms have generally become more widespread and intense due to raised nutrient levels in the environment. Typical nutrient sources from human activity in Scotland include discharges from sewage works, industry and agriculture.

7.25 Information on reducing nutrient enrichment of surface waters from agricultural sources can be found in *Prevention of Environmental Pollution from Agricultural Activity Code of Good Practice (2005)* which is available from the Scottish Executive (http://www.scotland.gov.uk/Publications/2005/03/20613/51366). Methods for preventing nutrient losses from urban areas are included in the *Sustainable Urban Drainage Systems – Design Manual for Scotland and Northern Ireland (2000)* **(http://www.sepa.org.uk/dpi/suds/)**. Further information and guidance can also be found in the 2003 WHO Guidance document for recreational waters. It is likely that SEPA will take account of such matters under the EC Water Framework Directive. (http://www.sepa.org.uk/wfd/). SEPA are developing ecological classification systems based on the condition of biological communities, to help assess the ecological quality of surface waters in response to environmental pressures. Furthermore, SEPA regulates activities such as abstraction, impoundment and engineering activities, as well as pollution, under the **Water Environment (Controlled Activities) Regulations 2005**.

7.26 Reducing nutrient inputs from the catchment is part of the long-term solution to the cause of algal blooms, but other measures may be effective in reducing these symptoms in the short-term. These measures include the use of barley straw, biomanipulation, increased flushing, forced circulation and chemical control.

Barley straw – This method involves the use of (small) bales or nets of barley straw submerged at the inlet to the water body and at other suitable locations. It is variably effective and then usually only in small water bodies. Further details are available at: **http://www.ceh.ac.uk/sections/wq/CAPMInformationsheets.htm**

Biomanipulation – The aim here is to make the aquatic ecosystem less conducive to algal blooms. Approaches include interventions aimed at increasing the populations of zooplankton (which feed on algae) and of aquatic macrophytes (plants that are large enough to be distinguishable from algae) which compete with algae for light and nutrients. The first of these might involve manipulation of the fish community to reduce the rate of zooplankton predation by fish. Macrophytes, e.g. reeds, can be used in constructed wetlands which can act as filter-beds to reduce nutrient concentrations before water enters a lake. The second approach can involve active planting of native water plants.

Increased flushing – if regulation of water entering or leaving the water body is controlled, it may be possible to optimise flushing to reduce nutrient concentrations and algal blooms.

Forced circulation – Water circulation can be forced by a wind- or electrically-driven turbine within the water body, or by sparging with compressed air. This ensures that the water body is evenly mixed and reduces internal release of phosphorus from the bottom sediments of the water body under anaerobic conditions. It also forces the algal cells to spend an increasing proportion of the day away from sunlight.

Chemical control methods – Precipitating agents have been used to encourage binding of phosphorus to sediments (reduce internal release); their application is not, however, recommended without expert guidance. Certain algaecides and herbicides have indicative

approval for use on or near waters in the UK. However, proposed use of any control chemicals on or near waters in Scotland must be notified to SEPA for approval where appropriate.

Further information on catchment management, biomanipulation and other control methods can be obtained from the Centre for Ecology and Hydrology (Annex C).

7.27 In exceptional circumstances, blue-green algal scums and mats may have to be removed and disposed of. Disposal of waste that has certain hazardous properties ("Hazardous waste" as defined by Article 1(4) of the **Hazardous Waste Directive**) will have to comply with the requirements of the Hazardous/Special Waste Regulations. Further details and information is available from SEPA (**http://www.sepa.org.uk/guidance/index.htm#waste**).

8 Information

8.1 Provision of public information on the local risks from blue-green algal blooms – both directly (using, for example, leaflets) and through the news media is seen as important and is a requirement where identified bathing waters are affected.

8.2 Responsibility for the provision of information is likely to lie primarily with the owners of waters, employers and others similarly placed. However, local authorities, Scottish Water, SEPA and NHS Boards should consider when, by whom, and with what content, information which comes to their attention on blue-green algal blooms should be given to:

- water-owners;
- other official bodies;
- those engaged in healthcare – in particular, those providing haemodialysis services, General Practitioners and Veterinary Surgeons;
- those with identifiable interests – for example, those receiving haemodialysis, farmers, members of canoe and angling clubs and recreational authorities;
- the news media; and
- the public.

8.3 Active provision of information to the news media is considered in Annex I.

8.4 While local authorities, Scottish Water, SEPA and NHS Boards will have differing lead responsibilities (for example, NHS Boards in the assessment of and response to enquiries from the public on hazards to human health), it would be helpful for agreement, as far as possible, between interested official bodies, on the content of both press releases and of information used by staff when responding to enquiries from the public.

9 Enforcement

9.1 Responsibilities for enforcement measures in respect of blue-green algae in inland waters fall into four general areas. These are, (i) minimising the incidence or severity of algal-blooms by control of aquatic eutrophication or treatment of affected waters, (ii) minimising the scope for direct contact with affected waters for people (workers and the general public) and animals, (iii) control of algal toxins in drinking water and (iv) control of algal toxins in food.

9.2 Enforcement provisions are further complicated by the large number of "stakeholders" involved. Table 9.1 therefore gives a general overview of their roles and responsibilities in this connection.

Table 9.1:
A general overview of the interests and responsibilities of the various stakeholders relevant to enforcement of provisions for mitigating the risk of health effects due to blue-green algae in inland waters.

Stakeholder	Interests and responsibilities
Water owners	Owners have a general duty to be vigilant to any factors relating to their property that might reasonably be considered to present a risk to members of the public or to animals. A need for particular vigilance often applies in the case of children. Owners must also take reasonable actions to inform and protect those who might be at risk. In these connections, decisions of what was "reasonable" would ultimately be a matter for the courts. The owner of the land on which a private drinking water source is located is responsible for controlling any activities on their land that might affect the supply to the extent that blue-green algal mass growths might be such as to breach the quality standards.
Members of the public	Members of the public are responsible for taking reasonable action to protect themselves, their children and their animals. Common law provides that persons may not recklessly or wilfully bring harm on themselves and then seek compensation from others. However, the extent to which they had done so would ultimately be a matter for the courts.
Health Protection Scotland (HPS)	HPS is the principal focus in Scotland, within the NHS, for advice on issues relating to health risks associated with infectious diseases and environmental hazards, including water contamination related incidents. HPS carries out surveillance of algal incidents, which have affected or have the potential to affect human health, using the Scottish Environmental Incident Surveillance System (SEISS), an on-line electronic reporting system for SEPA, Local Authorities and NHS Boards. Data on incidents is available via a password protected site to registered users and annual reports are provided via the HPS weekly report and website.

Table 9.1 (continued)

Stakeholder	Interests and responsibilities
NHS Boards	NHS Boards in Scotland are accountable to the Scottish Executive Health Department for the overall assessment of health needs of all people within their geographic areas, for arranging for those needs to be met and for providing public health advice to the public. They are also responsible for provision of medical advice to Scottish Water and (via the Designated Medical Officer) to the local authorities. The local NHS Board should take the lead in co-ordinating the development of a LAP for its area.
Scottish Poisons Information Bureau (SPIB)	The principal source in Scotland for information on toxicology and clinical management for hazardous substances. SPIB manages TOXBASE, a database that provides information on toxicology and treatment for poisons (including blue-green algal toxins) to registered users.
Health and Safety Executive	The HSE is responsible for enforcement of relevant "employers" legislation.
Employers	Employers must comply with the general and specific provisions of the following legislation in respect of their employees and any members of the public that might be affected by their business: The Health and Safety at Work etc Act 1974 The Control of Substances Hazardous to Health (COSHH) Regulations 2002 (As amended). The Management of Health and Safety at Work (MHSWR) Regulations 1999. Specific provisions of the MHSWR include the need for risk assessments and these should include any risks associated with exposure to blue-green algae or their toxins. Employers must then provide information, instruction and training in respect of these risks and their mitigation, in order to ensure safe systems of work.
Scottish Executive Environment and Rural Affairs Department (SEERAD)	SEERAD has overall responsibility for the regulatory framework for the water industry in Scotland and through the office of the Drinking Water Quality Regulator (DWQR) is responsible for ensuring compliance by Scottish Water with specified drinking water quality standards. SEERAD also oversee other legislation relevant to blue-green algae in Scottish waters including: The Bathing Water (Classification) (Scotland) Regulations 1991 and their forthcoming revision in 2007. The Surface Water (Fishlife) (Classification) (Scotland) Regulations 1997 The Surface Water (Abstraction for Drinking Water) (Classification) (Scotland) Regulations 1996. Sludge (Use In Agriculture) Regulations 1989 (as amended).

Table 9.1 (continued)

Stakeholder	Interests and responsibilities
Drinking Water Quality Regulator for Scotland (DWQR)	DWQR is responsible for ensuring compliance by Scottish Water with specified drinking water quality standards. DWQR therefore ensures compliance with the Water Supply (Water Quality) (Scotland) Regulations 2001.
Local Authorities (LAs), (mainly through Environmental Health Officers)	The general powers and responsibilities for Scottish Local authorities are defined in the Local Government (Scotland) Act 1973. The general functions of LAs in relation to water quality are defined in Section 76F(1) of the Water (Scotland) Act 1980. The Private Water Supplies (Scotland) Regulations 2006 define standards of wholesomeness in respect of water from private supplies for drinking, washing or cooking or for food production purposes. The 2006 Regulations distinguish between supplies serving less than 50 persons that have no commercial activity associated with them (Type B supplies) and all other supplies (Type A supplies). LAs are the regulators and have powers and responsibilities for classification and monitoring of waters and for enforcement of the relevant provisions. Pollutants, including blue green algae, to be monitored under these regulations are not specified precisely . However, Section 76G(1) of the Water (Scotland) Act 1980 provides that where a local authority considers that a private supply is likely not to be wholesome; "the local authority shall, in the case of a private supply which is a Type A supply or may, in the case of a private supply which is a Type B supply serve a notice in relation to that supply on one or more of the relevant persons". The LA also has general powers and responsibilities under the Local Government (Scotland) Act 1973 for the protection of the local population from environmental hazards such as algal toxins in recreational waters. LAs should co-operate with others in the development and implementation of the LAP.

Table 9.1 (continued)

Stakeholder	Interests and responsibilities
Scottish Water	Scottish Water is responsible for the cleanliness and safety of public water supplies for homes and businesses throughout Scotland. Duties are defined by the provisions of: The Water (Scotland) Act 1980 as amended The Water Industry (Scotland) Act 2002 The Water Environment and Water Services (Scotland) Act 2003 The Water Services etc. (Scotland) Act 2005 The Water Supply (Water Quality) (Scotland) Regulations 2001 Enforcement provisions include surveillance and analysis for the presence of potentially hazardous substances including algal toxins in the water that they supply. Scottish Water should co-operate with others in the development and implementation of the LAP.
SEPA	SEPA is responsible for ensuring compliance with environmental legislation, in particular: The Control of Pollution Act 1974 The Environmental Protection Act 1990 The Environment Act 1995 The Water Environment and Water Services (Scotland) Act 2003 The Water Environment (Controlled Activities) (Scotland) Regulations 2005 The Bathing Water (Classification) (Scotland) Regulations 1991 and their forthcoming revision in 2007. SEPA will co-operate with others in the development and implementation of the LAP.

Table 9.1 (continued)

Stakeholder	Interests and responsibilities
The Food Standards Agency Scotland (FSAS)	The FSA was established under the Food Standards Act 1999 as an independent food safety watchdog to protect the public's health and consumer interests in relation to food. The FSA's principal interest in blue-green algae is therefore any effect that they might have on the human food chain or on food processing. The FSA is not responsible for drinking water. To fulfil the Community obligations as Competent Authority the Agency designates, monitors and controls production areas for live bivalve molluscs. The main concern in Scotland is biotoxins in marine shellfish in relation to which the FSA has powers and responsibilities under Regulation (EC) 854/2004. Under Regulation (EC) 854/2004 FSA operates an official control monitoring programme to monitor for biotoxins in live bivalve molluscs from classified shellfish production areas, and for the presence of toxin-producing plankton in these areas. When toxins for Amnesic Shellfish Poisoning (ASP), Paralytic Shellfish Poisoning (PSP) or Diarrheic Shellfish Poisoning (DSP) are found to exceed the maximum permitted levels a Temporary Closure Notice (TCN) is made to close a classified area. Wild King Scallops (Pectinidae) harvested outside classified areas in Scotland are also monitored for the presence of biotoxins. Where regulatory levels are exceeded for wild Pectinidae placed on the market they must be withdrawn and where appropriate the issuing of a Food Alert, and RASSF (Rapid Alert System Food and Feed) will be undertaken. In addition, shellfish processors and their products must comply with all the statutory requirements in Regulation (EC) No 853/2004 which lays down the hygiene requirements for the production and placing on the market of live bivalve molluscs. The EC regulations are enabled by the Food Hygiene (Scotland) Regulations 2006. If necessary, similar provisions could be made in respect of shellfish or fin-fish harvested from freshwaters in Scotland.

10 Investigation

10.1 While the protection of people and of animals must remain the first objective in the response to a blue-green algal bloom, investigation and recording of adverse effects, should be carried out wherever possible.

10.2 In cases involving animals, particularly where deaths of livestock, wildlife and pets are thought to be associated with the ingestion of blue-green algae, it is important that an investigation is carried out. The owner should be referred to his or her veterinary surgeon who will decide whether to submit carcasses and samples to the local Veterinary Centre of the Scottish Agricultural College Veterinary Science Division (SACVSD) for post-mortem examination and further testing. The SAC Veterinary Centre will report findings to the submitting veterinary surgeon and, in the case of positive results, to the relevant Environmental Health Department.

10.3 It would be helpful to SACVSD if Environmental Health Departments could inform the Inverness Centre (Annex C) of incidents involving animals whether or not carcasses and samples of algae are available.

10.4 Where people or animals are thought to have been affected by blue-green algae, samples of blue-green algal material and, if appropriate, clinical samples (e.g. stomach or rumen contents, liver) should be taken. Advice on sampling is available (Annex C).

10.5 HPS should be informed of any algal incidents involving suspected or confirmed illness associated with exposure to blue-green algal blooms or their toxins, via the Scottish Environmental Incident Surveillance System (SEISS). This will ensure comprehensive surveillance of the health impact of episodes.

Membership of the working group Annex A

Member	Affiliation
Dr C Ramsay (Chairman)	Health Protection Scotland
Dr A M Johnston (Secretary)	SEHD
Prof D N Bateman	Scottish Poisons Information Bureau
Dr L Carvalho	Centre for Ecology and Hydrology
Professor G A Codd	University of Dundee (Biological Sciences)
Dr R Hermanns	HSE Employment Medical Advisory Service
Dr L Kelly	SEERAD Water Division
Dr J Krokowski	Scottish Environment Protection Agency
Mr F Reid	Scottish Water
Dr Jacqui McElhiney	Food Standards Agency Scotland
Dr J Cavanagh	Consultant in Public Health Medicine, NHSTayside
Mr C McLaren	SEERAD, Drinking Water Quality Regulator for Scotland

Blue-green algal toxins Annex B

Neurotoxins are produced by several species of blue-green algae, including species of *Anabaena, Aphanizomenon and Oscillatoria*. Several *Anabaena* neurotoxins exist, the most common of which (anatoxin-a) causes depolarisation block at neuromuscular junctions. Another neurotoxin (anatoxin-a(s)) is a naturally-occurring organophosphate product which inhibits acetylcholinesterase. *Aphanizomenon* toxins have been identified as alkaloids of the same group as those responsible for paralytic shellfish poisoning. Signs of poisoning in animals that have ingested blue-green algal neurotoxins have included paralysis, cyanosis, respiratory arrest, muscular tremor, hypersalivation, staggering and convulsions.

Hepatotoxins produced by several blue-green algae, including species of *Anabaena, Microcystis, Oscillatoria, Nostoc, Nodularia, Coelosphaerium and Gomphosphaeria*, have been identified as cyclic peptides. The hepatotoxins (microcystins) include over 80 variants; typically, several are present in a single hepatotoxic bloom. Signs of poisoning in animals have included weakness, vomiting, cold extremities, piloerection, diarrhoea, heavy breathing and death due to circulatory failure within 2 to 24 hours. Microcystins have also been associated with atypical pneumonia and are potent tumour promoters in laboratory animals. Nodularin, also a hepatotoxic tumour-promoter, is a carcinogen. Blue-green algae also produce lipopolysaccarides (LPSs) as normal components for their outer layers. The chemical composition of LPSs varies between strains of individual blue-green algal species. LPS may have contributed to skin irritation observed in swimmers in contact with blue-green algal blooms in the UK and to gastrointestinal disorders associated with blooms in several countries.

For sources of advice on toxicity see Annex C.

Sources of specialist advice Annex C

	Sources of advice	Advice on or assistance in
1.	The Centre for Ecology and Hydrology Bush Estate Penicuik Midlothian EH26 OQB Tel: 0131 445 4343 Fax: 0131 445 3943	Ecology and control of blue-green algae
2.	Scottish Environment Protection Agency (SEPA) South East Region Clearwater House Heriot-Watt Research Park Avenue North Riccarton Edinburgh EH14 4AP Tel: 0131 449 7296 North Region Greyhope House Greyhope Road Aberdeen AB11 9RD Tel: 01224 248338 South West Region 5 Redwood Crescent East Kilbride G74 5PP Tel: 01355 574200 Email: jan.krokowski@sepa.org.uk	Advice and assistance in analysis of samples from recreational waters. Determination of sources of pollution, their regulation and control.
3.	University of Dundee College of Life Sciences Division of Environmental and Applied Biology, Dundee DD1 4HN Tel: 01382 384272 Fax: 01382 384275 Email: g.a.codd@dundee.ac.uk	Analysis and assessment of algal toxins. Identification and quantification of toxin-forming and non-toxin-forming species. Control and removal of blue-green algal cells and toxins in water.

	Sources of advice	Advice on or assistance in
4.	The Scottish Poisons Information Bureau (SPIB) Royal Infirmary of Edinburgh, Edinburgh EH10 4SA Tel 0131 242 1383 (Office hours) Tel: 0870 6006266 (NPIS 24 hour telephone information line) Email: -mail: spib@luht.scot.nhs.uk Toxbase on line at: http://www.spib.axl.co.uk	Treatment of acute effects. Advice on possible long-term effects
5.	Health Protection Scotland Clifton House Clifton Place Glasgow G3 7LN Tel: 0141 300 1100 (office hours) 0141 211 3600 (out of hours) Fax: 0141 300 1170 Email: Colin.Ramsay@hps.scot.nhs.uk	Action to protect people and animals Investigation of health effects on people
6.	The Scottish Agricultural College Veterinary Science Division Veterinary Centre Drummondhill Stratherrick Road Inverness. IV2 4JZ Tel: 01463 243030 Fax: 01463 711103 Email: VCInverness@ed.sac.ac.uk	Investigation of health effects on animals
7.	Water Research Centre Frankland Road Blagrove Swindon Wilts SN5 8YF Tel 01793 865000 fax 01793 865001 Email solutions@wrcplc.co.uk	Assessment of drinking water quality
8.	The Health and Safety Executive Info-Line Tel: 08701 545500 Email: hseinformationservices@natbrit.com	Advice on employers' duties

Blue-green algae monitoring and action plan for xxxx NHS Board area

Sections

Tables

Recognition and identification of blue-green algal blooms, scums and mats and methods for sampling Annex E

Recognition

Scottish waters can support numerous different species of algae which can "bloom", either as individual species or in combination, when suitable ecological conditions occur. Some ("planktonic") species exist as single cells or colonies of cells suspended in the water, whereas other ("benthic") species may grow on the sediment along the shallow margins of waterbodies and occasionally form thick, slimy attached or detached mats.

When blooms of planktonic blue-green algae occur, it is often possible to see colonies of algal cells in the water column with the naked eye. These may resemble fine grass cuttings or take the form of small irregular clumps or pinhead-sized spheres. These colonies will concentrate on a downwind shore and sometimes accumulate to such an extent as to form a "scum" which is a thick (often many centimetres) layer of blue-green algae. They may also be seen in rivers or streams downstream of lochs.

When the blue-green algal cells start to die and break up, any toxins that may be present are released into the surrounding water. Cell pigments are also released resulting in a scum resembling turquoise emulsion paint spilt along the shore. It is important to note that not all blue-green algae are blue-green. They can range from black through dark brown to khaki, green to blue, and dark red. Decaying blue-green algae can appear sky-blue, grey and white.

There are only a few other types of algae (e.g. harmless *Euglena, Botryococcus*) that will occasionally form scums which can be confused with blue-green algal scums. Growths of some aquatic macrophytes, particularly duckweed (*Lemna*), and filamentous algae are also commonly mistaken for blue-green algal scum by inexperienced observers.

Benthic blue-green algae can be found in both standing and running waters. The algal mats that these occasionally form can become a problem if the water level drops and exposes the mat, or in some cases, they may detach from the bed, rise to the surface and may then be washed up on the shore. These detached mats are often very different in appearance to planktonic forms. They are usually very dark in colour (black, dark brown or dark green). They are much more cohesive in nature than planktonic scums and can be mistaken for sewage or cow dung. For example, a planktonic scum will flow into a bottle as a liquid whereas benthic scum will be lumpy and often have to be scooped into a bottle or jar.

Sampling equipment

Blue-green algae can be sampled easily and cheaply using simple equipment comprising:

- Sample bottles of suitable size, e.g. 1 litre plastic bottle for planktonic forms; vials or jars minimum size 30 ml for benthic forms.
- Plastic bucket tied to a rope (optional).
- Field data sheets or notebook.
- Self-adhesive labels or waterproof marker.

- Preservative (Lugol's iodine) if available can be added to a second sample bottle, which may be necessary only if it is likely that the samples will not be analysed within 24-48 hours. Lugol's iodine should not be added to samples if these are required for toxin analysis.
- Picnic-style insulated hamper box with chiller packs, to keep samples cool if transportation delays are expected.

Sampling health and safety

BLUE-GREEN ALGAE MAY PRODUCE TOXINS HAZARDOUS TO HUMAN HEALTH. CARE SHOULD BE TAKEN TO AVOID INGESTING OR COMING INTO DIRECT SKIN CONTACT WITH BLUE-GREEN ALGAL SCUM AND MAT MATERIAL. WEAR WELLINGTON BOOTS AND SUITABLE WATERPROOF GLOVES AND THOROUGHLY WASH HANDS BEFORE EATING OR DRINKING.

LUGOL'S IODINE IS A SKIN IRRITANT AND IS HARMFUL IF INGESTED IN QUANTITY. EYE PROTECTION AND SUITABLE RUBBER GLOVES MUST BE WORN WHEN HANDLING THIS CHEMICAL. THE PRESERVATIVE SHOULD BE ADDED IN A WELL-VENTILATED ENVIRONMENT.

NORMAL HEALTH AND SAFETY PRECAUTIONS SHOULD BE TAKEN FOR WORKING IN OR NEAR WATER (with specific regard to information, instruction and training, avoidance of working alone, ensuring communications in case of emergency, wearing a life jacket and suitable clothing).

Sampling procedure

Samples are normally collected from a point on the downwind shore of a waterbody where the concentration of blue-green algae is greatest. This may not be obvious to the naked eye, in which case any suitable site on the downwind shore can be selected. Bear in mind that blue-green algae will often collect in sheltered bays and inlets. If the downwind shore is inaccessible, then the waterbody should be sampled at the nearest accessible point to the downwind shore and this should be noted on the field data sheet or in a notebook.

In large lochs or inshore waters it is usually impractical to examine the whole downwind shore, in which case one or more samples should be taken at selected points.

Planktonic blue-green algae or floating benthic scums are sampled at or just below the water surface, preferably by taking a sample with a bucket and transferring the blue-green algae or scum sample into a pre-labelled bottle, or by directly immersing a pre-labelled bottle and filling it completely. Occasionally it may be difficult to reach open water, for example, because of dense emergent vegetation. In such cases a bucket on a rope may be a useful aid. Benthic blue-green algae which might be attached to sediment or stones or have become detached, may need to be scooped into a wide-mouthed jar. If waterlevels have fallen, scums and mats may be stranded on the shoreline and scooped or scraped directly into a container.

The following information should be recorded on the sample bottle label:

- Name of waterbody.
- Water body code (from http://www.uklakes.net/), available for the larger waterbodies only.
- Sample identifier (site name or number).
- National grid reference of sampling site.
- Date and time of sampling.
- Name or initials and contact details (telephone or email) of sampler.

Additional information useful to the analyst should be recorded on a field data sheet or in a notebook or communicated via email or telephone. This should include:

- Sampling location. For waterbodies which are sampled regularly, it may be more convenient to include an outline map on the field sheet so that the position of the sampling site can be marked on.
- The presence and extent of any blue-green algal scum or mats. For small easily surveyed waterbodies an estimate of percentage cover of the water surface or shoreline could be made or the position of any scum or mat could be drawn on an outline map.
- The presence of any visible blue-green algal growths in the water column.
- The direction and strength of the wind.

Sample handling

Samples should be kept in cool, dark conditions, e.g. in an insulated picnic style hamper box and transported to the laboratory as quickly as possible. If this cannot be achieved within 24 hours then aliquots of the samples should be preserved for microscopy by adding Lugol's iodine solution (note previous Health and Safety instructions). Sufficient should be added to turn the sample a dark straw colour.

Samples for toxin analysis should be stored in a cool box after collection and transferred to a refrigerator at about 4°C, but not frozen, if analysis is possible within 48 hours. If not possible within this period, samples for toxin analysis should be deep-frozen

Sample analyses

Where appropriate capability exists, samples can be analysed locally. Alternatively, (as indicated in Section 5) various organisations including SEPA and Scottish Water can provide an analytical service to identify and quantify algal blooms in samples taken by others.

Standard operating procedures are used to quantify the type of blue-green algae present, and blue-green algal abundance is compared against WHO guidance levels. The identification of dominant blue-green algae will be to genus level as a minimum requirement and to species level wherever possible.

Toxicity assessment and toxin analysis (see Annex C) testing may be carried out as a further aid to the management of algal blooms or scum on waterbodies with high recreational amenity value or on waterbodies used to supply potable water.

Further information

Further information and advice can be obtained from Ecology staff at SEPA Regional and Area offices. Contact details are given here in Annex C.

Suggested templates for risk assessments Annex F

Proactive assessment of the risk to public health of high concentrations of blue-green algae

Name of water: High Loch Map reference: X 1 0 Y 1 0

Owner: The Local Authority (Leased to Hightown Angling Association)

Occurrence

Typical pattern of frequency and occurrence of algal blooms:

Typically one algal bloom occurs most (but not all) years usually in late August or September. The intensity varies greatly but the typical duration would be less than two weeks.

Occurrence category: 2

Usage

How is the waterbody used?

Neither the loch nor any of its incoming or outgoing streams is used as a source of public or private drinking water. There is a path around the loch that is used by anglers and walkers (often with dogs). Cattle drink from the loch and its associated streams. The local canoe club uses the loch about three times each year always in summer.

Risk category: Medium to high

Monitoring and control of risks

Blooms tend to be short-term and are likely to be missed by a planned monitoring programme. No planned inspection or monitoring programme will be undertaken. The local angling association (AA) and the canoe club have both been advised of the risks and provided with leaflets. They have undertaken to advise the local authority of the appearance of blooms. A reactive risk assessment will then consider the need for reactive inspection and/or monitoring. Warning signs are kept in the AA hut and will be placed by the AA at pre-defined locations when a bloom appears. Further interventions will be considered in the reactive risk assessment.

Signed John Smith Date 0 1/0 1/0 1

Print name John Smith. Senior EHO.

Reactive assessment of the risk to public health of high concentrations of blue-green algae

Name of water: High Loch Map reference: X 1 0 Y 1 0

Owner: Hightown Angling Association

Usage

How is the waterbody used?

Neither the loch nor any of its incoming or outgoing streams is used as a source of public or private drinking water. There is a path around the loch that is used by anglers and walkers (often with dogs). Cattle drink from the loch and its associated streams. The local canoe club uses the loch about three times each year always in summer.

Risk category: Medium to high.

Recognition

How and when was the bloom detected and reported?

The local authority was informed of the appearance of a bloom by Mr J Jones of the Hightown Angling Association by telephone on 26/8/02.

Health effects

Have any animal or human health effects been reported? ~~Yes~~/No

If yes please specify.

Actions

What actions have been taken to date?

Warning signs have been placed by the local Angling Association at pre-defined locations. The regional EHO has inspected the loch and has sent water samples to SEPA for analysis. The local farmer has been advised to move cattle from an adjacent field which provides access to water from the loch, until further notice. The canoe club has been informed.

What further actions are planned?

A further inspection will be carried out on 7/9/02.

Signed. John Smith Date. 29/08/02

Print name. John Smith. Senior EHO.

Extract on exposure guidelines from the WHO Document Annex G

Guidelines for Safe Recreational-water Environments 2003
Vol. 1: Coastal and Fresh-waters October 1998

8.7 Guideline values

As discussed above, approaches to recreational water safety should address the occurrence of cyanobacteria as such, because it is as yet unclear whether all important cyanotoxins have been identified, and the health outcomes observed after recreational exposure – particularly irritation of the skin and mucous membranes – are probably related to cyanobacterial substances other than the well known toxins listed in Table 8.1. Additionally, the particular hazard of liver damage by microcystins should be considered. In face of the difficulty of representative quantitative sampling due to the heterogeneous distribution of cyanobacteria in time and space, particularly with respect to scum formation and scum location, approaches should further include addressing the capacity of a water body to sustain large cyanobacterial populations. Health impairments from cyanobacteria in recreational waters must be differentiated between the chiefly irritative symptoms caused by unknown cyanobacterial substances and the potentially more severe hazard of exposure to high concentrations of known cyanotoxins, particularly microcystins. A single guideline value therefore is not appropriate. Rather, a series of guideline values associated with incremental severity and probability of health effects is defined at three levels (Table 8.3).

8.7.1 Relatively low probability of adverse health effects

For protection from health outcomes not due to cyanotoxin toxicity, but rather to the irritative or allergenic effects of other cyanobacterial compounds, a guideline level of 20,000 cyanobacterial cells/ml (corresponding to 10µg chlorophyll-a/litre under conditions of cyanobacterial dominance) can be derived from the prospective epidemiological study by Pilotto *et al*. (1997). Whereas the health outcomes reported in this study were related to cyanobacterial density and duration of exposure, they affected less than 30% of the individuals exposed. At this cyanobacterial density, 2– 4µg microcystin/litre may be expected if microcystin-producing cyanobacteria are dominant, with 10µg/litre being possible with highly toxic blooms. This level is close to the WHO provisional drinking-water guideline value of 1µg/litre for microcystin-LR (WHO, 1998), which is intended to be safe for lifelong consumption. Thus, health outcomes due to microcystin are unlikely, and providing information for visitors to swimming areas with this low-level risk is considered to be sufficient. Additionally, it is recommended that the authorities be informed in order to initiate further surveillance of the site. The results of the epidemiological study (Pilotto *et al*., 1997) reported some mild irritative effects at 5,000 cells but the level of health effect and the small number of people affected were not considered to be a basis to justify action.

8.7.2 Moderate probability of adverse health effects

At higher concentrations of cyanobacterial cells, the probability of irritative symptoms is elevated. Additionally, cyanotoxins (usually cell-bound) may reach concentrations with potential health impact. To assess risk under these circumstances, the data used for the drinking-water provisional guideline value for microcystin-LR may be applied. Swimmers involuntarily swallow some water while swimming, and the harm from ingestion of recreational water will be comparable to the

harm from ingestion of water from a drinking-water supply with the same toxin content. For recreational water users with whole-body contact (see chapter 1), a swimmer can expect to ingest 100–200 ml of water in one session, sailboard riders and waterskiers probably more.

A level of 100,000 cyanobacterial cells/ml (which is equivalent to approximately 50µg chlorophyll-a/litre if cyanobacteria dominate) represents a guideline value for a moderate health alert in recreational waters. At this level, a concentration of 20µg microcystin/litre is likely if the bloom consists of *Microcystis* and has an average toxin content of 0.2 pg/cell, or 0.4µg microcystin/µg chlorophyll-a. Levels may be approximately double if *Planktothrix agardhii* dominates. With very high cellular microcystin content, 50–100µg microcystin/litre would be possible.

The level of 20µg microcystin/litre is equivalent to 20 times the WHO provisional guideline value concentration for microcystin-LR in drinking-water (WHO, 1998) and would result in consumption of an amount close to the tolerable daily intake (TDI) for a 60-kg adult consuming 100 ml of water while swimming (rather than 2 litres of drinking-water). However, a 15-kg child consuming 250 ml of water during extensive playing could be exposed to 10 times the TDI. The health risk will be increased if the person exposed is particularly susceptible because of, for example, chronic hepatitis B. Therefore, cyanobacterial levels likely to cause microcystin concentrations of 20µg/litre should trigger further action.

TABLE 8.3.
GUIDELINES FOR SAFE PRACTICE IN MANAGING RECREATIONAL WATERS[a]

Guidance level or situation	How guidance level derived	Health risks	Typical actions[b]
Relatively low probability of adverse health effects			
20,000 cyanobacterial cells/ml or 10µg chlorophyll-a/litre with dominance of cyanobacteria	• From human bathing epidemiological study	• Short-term adverse health outcomes, e.g. skin irritations, gastrointestinal illness	• Post on-site risk advisory signs • Inform relevant authorities
Moderate probability of adverse health effects			
100,000 cyanobacterial cells/ml or 50µg chlorophyll-a/litre with dominance of cyanobacteria	• From provisional drinking-water guideline value for microcystin-LR[c] and data concerning other cyanotoxins	• Potential for long-term illness with some cyanobacterial species • Short-term adverse health outcomes, e.g. skin irritations, gastrointestinal illness	• Watch for scums or conditions conducive to scums • Discourage swimming and further investigate hazard • Post on-site risk advisory signs • Inform relevant authorities
High probability of adverse health effects			
Cyanobacterial scum formation in areas where whole-body contact and/or risk of ingestion/aspiration occur	• Inference from oral animal lethal poisoning • Actual human illness occur histories	• Potential for acute poisoning • Potential for long-term illness with some cyanobacterial species • Short-term adverse health outcomes, e.g. skin irritations, gastrointestinal illness	• Immediate action to control contact with scums; possible prohibition of swimming and other water contact activities. • Public health follow-up investigation. • Inform public and relevant authorities

[a] Derived from Chorus & Bartram, 1999.
[b] Actual action taken should be determined in light of extent of use and public health assessment of hazard.
[c] The provisional drinking-water guideline value for microcystin-LR is 1µg/litre (WHO, 1998).

Non-scum-forming species of cyanobacteria such as Planktothrix agardhii have been observed to reach cell densities corresponding to 250µg chlorophyll-a/litre or even more in shallow water bodies. Transparency in such situations will be less than 0.5 m measured with a Secchi disc. Planktothrix agardhii has been shown to contain very high cell levels of microcystin (1–2µg microcystin/µg chlorophyll-a), and therefore toxin concentrations of 200–400µg/litre can occur without scum formation.

An additional reason for increased alert at 100,000 cells/ml is the potential for some frequently occurring cyanobacterial species (particularly Microcystis spp. and Anabaena spp.) to form scums. These scums may increase local cell density and thus toxin concentration by a factor of 1,000 or more in a few hours, thus rapidly changing the risk from moderate to high for bathers and others involved in body-contact water sports. Cyanobacterial scum formation presents a unique problem for routine monitoring at the usual time intervals (e.g., 1 or 2 weeks) because such monitoring intervals are unlikely to pick up hazardous maximum levels. Because of the potential for rapid scum formation at a cyanobacterial density of 100,000 cells/ml or 50µg chlorophyll-a/litre (from scum-forming cyanobacterial taxa), intensification of surveillance and protective measures are appropriate at these levels. Daily inspection for scum formation (if scum-forming taxa are present) and measures to prevent exposures in areas prone to scum formation are the two principal actions important in these situations.

Intervention is recommended to trigger effective public information campaigns to educate people on avoidance of scum contact. Furthermore, in some cases (e.g., areas with frequent scum formation), restriction of water contact activities may be judged to be appropriate. An intensified monitoring programme should be implemented, particularly looking for scum accumulations. Health authorities should be notified immediately.

8.7.3 High probability of adverse health effects

Abundant evidence exists for potentially severe health outcomes associated with scums caused by toxic cyanobacteria. No human fatalities have been unequivocally associated with cyanotoxin ingestion during recreational water activities, although numerous animals have been killed by consuming water with cyanobacterial scum material. This discrepancy can be explained by the fact that animals will drink greater volumes of scum-containing water in relation to their body weight, whereas accidental ingestion of scums by humans during swimming will typically result in a lower dose.

Cyanobacterial scums can represent thousand-fold to million-fold concentrations of cyanobacterial cell populations. Calculations suggest that a child playing in Microcystis scums for a protracted period and ingesting a significant volume could receive a lethal dose, although no reports indicate that this has occurred. Based on evidence that a lethal oral dose of microcystin-LR in mice is 5,000–11,600µg/kg body weight and sensitivity between individuals may vary approximately 10-fold, the ingestion of 5–50mg of microcystin could be expected to cause acute liver injury in a 10-kg child. Concentrations of up to 24mg microcystin/litre from scum material have been published (Chorus & Fastner, 2001). Substantially higher enrichment of scums – up to gelatinous consistency – is occasionally

observed, of which accidental ingestion of smaller volumes could cause serious harm. Anecdotal evidence indicates that children, and even adults, may be attracted to play in scums. The presence of scums caused by cyanobacteria is thus a readily detected indicator of a risk of potentially severe adverse health effects for those who come into contact with the scums. Immediate action to control scum contact is recommended for such situations.

8.7.4 Conclusions

The approach outlined in this section does not cover all conceivable situations. Swimmers may be in contact with benthic cyanobacteria after a storm breaks off clumps of filaments or cyanobacterial mats naturally detach from the sediment and are accumulated on shorelines (Edwards *et al.*, 1992). Measures of cyanobacterial cell density will not detect these hazards. Instead, this cyanotoxin hazard calls for critical and well informed observation of swimming areas, coupled with a flexible response.

It is difficult to define "safe" concentrations of cyanobacteria in recreational water for allergenic effects or skin reactions, as individual sensitivities vary greatly. Aggravation of dermal reactions due to accumulation of cyanobacterial material and enhanced disruption of cells under bathing suits and wet suits may be a problem even at densities below the guideline levels described above.

TEMPORARY/PERMANENT* WARNING NOTICE
BLUE-GREEN ALGAL BLOOMS

HIGH CONCENTRATIONS OF BLUE-GREEN ALGAE HAVE BEEN FOUND IN THIS WATER.

SWALLOWING THE WATER OR ALGAL SCUM OR SHORELINE MATS CAN CAUSE STOMACH UPSETS OR MORE SERIOUS HEALTH EFFECTS.

CONTACT WITH THE WATER OR WITH ALGAL SCUM CAN CAUSE SKIN PROBLEMS.

IT IS A SENSIBLE PRECAUTION FOR YOU, YOUR CHILDREN AND YOUR ANIMALS TO AVOID CONTACT WITH THE SCUM, ALGAL MATS AND THE WATER CLOSE BY.

NOTICE POSTED ON: **<DATE>**

EFFECTIVE UNTIL:** **<DATE>**

NOTICE POSTED BY: **<NAME OF ORGANISATION>**

<ADDRESS>

FOR FURTHER INFORMATION
TELEPHONE

*AS APPROPRIATE **FOR TEMPORARY NOTICES ONLY

Media briefing notes Annex I

I1 Algal Bloom Initial Release on Discovery

<Day, Month, Year>

<Time>

For Immediate Release

BLUE-GREEN ALGAE

Recent samples taken at **<name of water body>** have indicated the presence of blue-green algae.

As a precautionary measure, notices have been posted next to the reservoir warning that contact with the algal scum or mat material should be avoided. *[If a bathing water: Information, including on site notices, have been provided to the public that bathing is inadvisable at this time.]*

Adjoining landowners and fishing interests have been advised of the situation as have the Environmental Health Department of **<Council>, <the SEPA office>** and **<NHS Board>**.

At this stage there is no adverse effect on water supplies.

Media Briefing Note:

- Blue-green algae exist in fresh waters in Great Britain and throughout the world; they are noticed when their concentrations increase to form "blooms" and when they form scums – looking like blue-green paint – or when they collect on the shore line as scums or mats.
- Some blue-green algae may give rise to adverse medical effects – but not always. Effects on people coming into contact with toxic scums include skin rashes, eye irritations, vomiting and diarrhoea, fever and pains in muscles and joints. Toxic algae have caused deaths of livestock and dogs, waterbirds and fish. The treatment of water supplies removes blue-green algae and additional treatment may be applied to destroy or remove toxins should they arise. The actions currently taken are precautionary.
- The behaviour of algae is erratic.
- The level of its toxicity can fluctuate; it can appear one day, be dispersed by the wind and mixing and re-accumulate at any time.

Ends

Press Contact: Corporate Communications, tel :**<<number>>**

I2 Algal Bloom if Toxicity has been established

<Day, Month, Year>

<Time>

For Immediate Release

BLUE-GREEN ALGAE

Further tests carried out by **<agency>** have shown that the blue-green algal bloom at **<name of water body>** has become active. **<<The reservoir is not being used for water supply. Alternative sources are being used>> // <<Additional treatment methods have been employed at <treatment works> to ensure our customers are not affected.>>** Daily monitoring of the supply is being carried out.

<Council> Environmental Health Department and **<NHS Board>** have been advised. Adjoining landowners have also been advised, and fishing and boating has been stopped as a precautionary measure. Members of the public have been advised to stay away from the reservoir.

Media Briefing Note:

- Blue-green algae exist in fresh waters in Great Britain and throughout the world; they are noticed when their concentrations increase to form "blooms" and when they form scums – looking like blue-green paint – or when they collect on the shore line.
- Some blue-green algae may give rise to adverse medical effects – but not always. Effects on people coming into contact with toxic scums include skin rashes, eye irritations, vomiting and diarrhoea, fever and pains in muscles and joints. Toxic algae have caused deaths of livestock and dogs. The treatment of water supplies removes blue-green algae and additional treatment may be applied to destroy or remove toxins should they arise. The actions currently taken are precautionary.
- The behaviour of algae is erratic.
- The level of its toxicity can fluctuate; it can appear one day, be dispersed by the wind and mixing and re-accumulate at any time.

Ends

Press Contact: Corporate Communications, tel :**<<number>>**

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